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# विद्युततकनीकी शब्दावली

## भाग 7 अर्द्धचालक युक्तियाँ एवं समाकलित परिपथ

( दूसरा पुनरीक्षण )

*Indian Standard*

# ELECTROTECHNICAL VOCABULARY

## PART 7 SEMICONDUCTOR DEVICES AND INTEGRATED CIRCUITS

*( Second Revision )*

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Semiconductor Devices and Integrated Circuits Sectional Committee, LTD 10

## FOREWORD

This Indian Standard ( Part 7 ) ( Second Revision ) was adopted by the Bureau of Indian Standards, after the draft finalized by the Semiconductor Devices and Integrated Circuits Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

Hitherto, this standard (Part 7) existed in six sections, namely, (a) Section 1 General; (b) Section 2 Diodes; (c) Section 3 Transistors; (d) Section 4 Thyristors; (e) Section 5 Integrated circuits and microelectronics; and (f) Section 6 Optoelectronic devices and was based on IEC 147-0 (1966). However, IEC 147-0 (1966) has been withdrawn.

With the advent of individual standards being drawn up for various semiconductor devices, need has been felt to cover many additional terms relating to the ratings and characteristics of these devices also in addition to covering terminology on new devices. The second revision of this standard, therefore, has been taken up with a view to bring together terms relating to semiconductor devices covering different aspects, such as general, processing, diodes, transistors, thyristors, microelectronics, optoelectronic devices, etc.

The revised version of this standard (Part 7) consolidates the provisions of all six sections into a single standard.

While preparing this standard assistance has been derived from IEC 50(521)-1984 'International electrotechnical vocabulary — Chapter 521 : semiconductor devices and integrated circuits', issued by the International Electrotechnical Commission. A section on 'Specific terms for optoelectronic devices' is also included in this standard which is not there in the IEC publication.

The contents of this standard are divided among the following sections:

| | |
|---|---|
| Section 1 | Introduction to atomic physics |
| Section 2 | Properties of semiconductor materials |
| Section 3 | Processing semiconductor materials |
| Section 4 | Types of semiconductor devices |
| Section 5 | General terms for semiconductor devices |
| Section 6 | Specific terms for diodes |
| Section 7 | Specific terms for transistors |
| Section 8 | Specific terms for thyristors |
| Section 9 | Specific terms for Hall-effect devices and magnetoresistors |
| Section 10 | Specific terms for integrated microcircuits |
| Section 11 | Specific terms for optoelectronic devices |

*Indian Standard*

# ELECTROTECHNICAL VOCABULARY

## PART 7 SEMICONDUCTOR DEVICES AND INTEGRATED CIRCUITS

*( Second Revision )*

## 1 SCOPE

**1.1** This standard (Part 7) covers terms relating to semiconductors, semiconductor devices and integrated circuits and their definitions.

## SECTION 1 INTRODUCTION TO ATOMIC PHYSICS

## 2 TERMS RELATED TO ATOMIC PHYSICS

### 2.1 Non-quantized System (of Particles)

A system of particles whose energies are assumed to be capable of varying in a continuous manner and in which the number of microscopic states defined by the positions and velocities of the particles at a given instant is therefore unlimited.

### 2.2 Quantized System (of Particles)

A system of particles the energies of which can have discrete values only.

### 2.3 Maxwell-Boltzmann Statistics

The probability distribution of the microscopic states of a non-quantized system of particles, defined by the average values of the position, velocity or energy co-ordinates, in a very small, but finite, volume of the system.

### 2.4 Boltzmann Relation

The equation stating that, apart from an additive constant, the entropy of a system of particles is equal to the product of the Napierian (natural) logarithm of the probability of its macroscopic state and the Boltzmann constant.

### 2.5 Maxwell-Boltzmann Velocity-Distribution Law

The algebraic equation giving the number d$N$ of particles of a non-quantized system, the components of velocity of which are comprised in the intervals ($u$, $u$+d$u$), ($v$, $v$+d$v$), ($w$, $w$+d$w$) respectively:

$$\mathrm{d}N = A \cdot \exp.\,[-\,m\,(u^2 + v^2 + w^2)/\,2kT\,]\;\mathrm{d}u \cdot \mathrm{d}v \cdot \mathrm{d}w$$

where

$A = N\,[\,m\,/\,(2\pi \cdot kT)]^{3/2}$

$N$ = total number of particles,
$m$ = mass of a particle,
$T$ = thermodynamic temperature, and
$k$ = Boltzmann constant.

NOTE — d$N$/$N$ represents the probability that a particle has its components of velocity within the intervals considered.

### 2.6 Bohr Atom

The model of the atom based on the conception of Bohr and Sommerfield, according to which the electrons of an atom move around the nucleus in discrete circular or elliptical orbits.

NOTE — To each of the degrees of freedom of the atom there corresponds a series of energy states which determine the spectral series that may be emitted by the atom.

### 2.7 Quantum Number (of an Electron in a Given Atom)

Each of the numbers characterizing the degree of freedom of an electron in a given atom:

— the principal quantum number $n$,
— the orbital quantum number $l$,
— the spin quantum number $s$,
— the total angular momentum quantum number $j$.

### 2.8 Principal Quantum Number, First Quantum Number ( Symbol : *n* )

The positive integer number characterizing the important changes of energy level of the electrons in an atom.

NOTE — According to the Bohr atom model, the main quantum number may be considered as characterizing the size of an electron orbit.

### 2.9 Orbital Quantum Number, Second Quantum Number ( Symbol : *l* )

A quantum number which can have all whole values from zero to $n - 1$, $n$ designating the main quantum number.

NOTE — According to the Bohr atom model, the orbital quantum number may be considered as characterizing the angular momentum of the electron in its orbital motion round the nucleus.

### 2.10 Spin Quantum Number ( Symbol : *s* )

A quantum number which gives the angular momentum of the electron considered as a small charged sphere revolving/rotating around its axis.

NOTE — The spin may have two values : + 1/2 or – 1/2.

### 2.11 Total Angular Momentum Quantum Number ( Symbol : *j* )

The quantum number which gives the resultant of the magnetic field engendered by the electron due to its orbital movement and due to its revolving on its own axis.

NOTE — The values of this number $j$ form a set of integral and semi-integral values.

### 2.12 Energy Level (of a Particle)

The energy associated with a quantum state of a physical system.

### 2.13 Energy-Level Diagram

A diagram representing the energy levels of the particles of a quantized system by horizontal lines, having for ordinates the energy of these particles.

### 2.14 Pauli-Fermi Exclusion Principle, Pauli Principle

The principle stating that each energy level of a quantized system can include only none, one or two particles.

NOTE — In the case of two electrons, the spins are of opposite sign.

### 2.15 Fermi-Dirac Statistics, Fermi Statistics

The set of probabilities of the macroscopic states of a quantized system of particles, with only discrete energy levels, obeying the Pauli-Fermi exclusion principle.

### 2.16 Fermi-Dirac Function

A function expressing the probability $P(E)$, for a particle obeying Fermi statistics, that it will occupy a permitted energy level ($E$),

$$P(E) = \frac{1}{1 + \exp.\left[(E - E_F)/kT\right]}$$

where

$k$ = boltzmann constant,
$T$ = thermodynamic temperature,
$E_F$ = Fermi level,
and where this level is quantized and may contain 0, 1 or 2 electrons.

### 2.17 Fermi-Level

In a solid, the energy level separating the occupied states from the unoccupied states at a temperature of zero Kelvin.

NOTE — When a forbidden band separates the occupied and unoccupied states, the Fermi-level is assigned to the centre of the forbidden band.

### 2.18 Lone Electron

An electron which is alone on an energy level.

### 2.19 Fermi-Dirac-Sommerfeld Velocity Distribution Law

The algebraic equation giving the number d$N$ of particles of a quantized system in equilibrium the velocity components of which are included in the intervals ($u$, $u$+d$u$), ($v$, $v$+d$v$), ($w$, $w$+d$w$) respectively:

$$\mathrm{d}N = 2N\frac{m^3}{h^3}\,\frac{\mathrm{d}u.\,\mathrm{d}v.\,\mathrm{d}w}{1 + \exp.\left[(E - E_M)/kT\right]}$$

where

$N$ = total number of particles,
$m$ = mass of a particle,
$T$ = thermodynamic temperature,
$k$ = boltzmann constant,
$h$ = planck constant,
$E$ = kinetic energy of the particle,

$$E = (m/2)(u^2 + v^2 + w^2)$$

$E_M$ = inner work function, and
d$N/N$ represents the probability that a particle has its components of velocity within the intervals considered.

### 2.20 Photoelectric Effect

An electrical phenomena produced by absorption of photons.

### 2.21 Photovoltaic Effect

A photoelectric effect in which an e.m.f. is produced by the absorption of photons.

### 2.22 Photoconductive Effect

A photoelectric effect characterized by the variation of electric conductivity.

### 2.23 Photoelectromagnetic Effect

In a semiconductor subjected to a magnetic field and electromagnetic radiation, the development of an electric field perpendicular to the magnetic field and to the flow of charge carriers generated by the photoelectric effect and diffusing in the semiconductor.

## SECTION 2 PROPERTIES OF SEMICONDUCTOR MATERIALS

## 3 TERMS RELATED TO PROPERTIES OF SEMICONDUCTOR MATERIALS

### 3.1 Semiconductor

A substance whose total conductivity due to charge carriers of both signs is normally in the range between that of metals and insulators and in which the charge carrier density can be changed by external means.

NOTE — The term 'semiconductor' generally applies where the charge carriers are electrons or holes.

### 3.2 Single-Element Semiconductor

A semiconductor which in the pure state consists of a single-element.

### 3.3 Compound Semiconductor

A semiconductor which in the pure state consists of several elements in proportions close to the stochiometric composition.

### 3.4 Impurity

a) Foreign atoms in a single-element semiconductor.

b) Foreign atoms or either an excess or a deficiency of atoms with respect to the stochiometric composition of a compound semiconductor.

### 3.5 Impurity Activation Energy

The gap between an intermediate energy level due to an impurity and the adjacent energy band.

### 3.6 Ionic Semiconductor

A semiconductor in which the conductivity due to the flow of ions predominates over that due to the motion of electrons and holes.

### 3.7 Intrinsic Semiconductor I-type Semiconductor

An effectively pure semiconductor in which, under conditions of thermal equilibrium, the charge carrier densities of each sign are practically equal.

### 3.8 Extrinsic Semiconductor

A semiconductor having impurities or other imperfections and in which the charge carrier densities of each sign are different.

### 3.9 N-type Semiconductor, Electron Semiconductor

An extrinsic semiconductor in which the conduction electron density exceeds the mobile hole density under conditions of thermal equilibrium.

### 3.10 P-type Semiconductor, Hole Semiconductor

An extrinsic semiconductor in which the mobile hole density exceeds the conduction electron density under conditions of thermal equilibrium.

### 3.11 Compensated Semiconductor

A semiconductor in which the effects of the impurities of a given type on the charge carrier density partially or completely cancel those of the other type.

### 3.12 Non-degenerate Semiconductor

A semiconductor in which the Fermi-level is situated in the energy gap away from the boundaries at a distance at least twice as great as the product of Boltzmann's constant and the thermodynamic temperature.

NOTE — The charge carriers in a non-degenerate semiconductor are governed by Maxwell-Boltzmann statistics.

### 3.13 Degenerate Semiconductor

A semiconductor in which the Fermi-level is situated in the conduction band, or in the valence band or is closer than twice the product of Boltzmann's constant and the thermodynamic temperature to either band.

NOTE — The charge carriers of a degenerate semiconductor are governed by Fermi Dirac statistics.

### 3.14 Conduction Electrons

The electrons in the conduction band of a semiconductor, which are free to flow under the action of an electric field.

### 3.15 Conduction Current

The directed movement of free charge carriers in a medium under the influence of an electric field.

### 3.16 Conductor

A substance having free charge carriers which can be moved by an electric field.

### 3.17 Hole

A vacancy appearing in a normally filled energy band, behaving like a positive charge carrier.

NOTE — A hole is frequently produced by the elevation of an electron from the valence band to the conduction band, this produces what is called an electron-hole pair.

### 3.18 Hole Conduction

A conduction in a semiconductor, in which holes in a crystal lattice are propagated through the lattice under the influence of an electric field.

### 3.19 Electron Conduction

A conduction in a semiconductor in which conduction electrons in a crystal lattice are propagated through the lattice under the influence of an electric field.

### 3.20 Intrinsic Conduction

A conduction in a semiconductor caused by the movement of holes and conduction electrons formed due to the thermal generation of pairs of charge carriers.

### 3.21 Ionic Conduction

A conduction caused by the directed movement of charges due to the displacement of ions, the movement being maintained by a continuous contribution of external energy.

### 3.22 Conduction Band

A permitted energy band partially occupied by electrons that are free to move under the influence of an external electric field.

### 3.23 Valence Band

The permitted band occupied by the valence electrons.

NOTES

1 The valence band in an ideal crystal is completely occupied at the temperature of zero Kelvin.

2 Electronic missing from the valence band give rise to conduction holes in the valence band and conduction electrons in the conduction band.

### 3.24 Energy Gap

The gap between the lower energy boundary of the conduction band and the upper energy boundary of the valence band.

### 3.25 Energy Band (Bloch Band)

A virtually continuous set of energy levels in a substance.

### 3.26 Energy Band (in a Semiconductor)

A range of energy levels of electrons in a semiconductor, limited by the minimum and maximum values of the energies.

### 3.27 Partially Occupied Band

An energy band not all the levels of which correspond to the energy of each of two electrons with opposite spins.

### 3.28 Excitation Band

An energy band having a range of neighbouring energy levels which correspond to possible excited states of the electrons of a substance.

### 3.29 Permitted Band

An energy band each level of which may be occupied by electrons.

### 3.30 Forbidden Band

An energy band that cannot be occupied by electrons.

### 3.31 Insulant

A substance in which the valence band is a filled band separated from the first excitation band by a forbidden band of such width that the energy needed to excite electrons from the valence band to the conduction band is so large as to disrupt the substance.

### 3.32 Filled Band

A permitted band in which, at a temperature of zero Kelvin, all the energy levels are occupied by electrons.

### 3.33 Empty Band

A permitted band in which, at a temperature of zero Kelvin, no energy level is occupied by electrons.

### 3.34 Surface Band

A permitted band formed by the surface levels of a crystal.

### 3.35 Local Level

An energy level in a forbidden band caused by a lattice imperfection in the case of a low concentration of defects.

### 3.36 Impurity Level

A local level due to the impurity.

### 3.37 Impurity Band

An energy band formed by the combination of impurity levels of one type and entirely or partially located in the forbidden band.

### 3.38 Donor

An imperfection in a crystal lattice which, when it is predominant, permits electron conduction by the donation of electrons.

### 3.39 Acceptor

An imperfection in a crystal lattice which, when it is predominant, permits hole conduction by the acceptance of electrons.

### 3.40 Donor Level

An intermediate impurity level close to the conduction band in an extrinsic semiconductor.

NOTE — The donor level is filled at the temperature of zero Kelvin: at any other temperature it can supply electrons to the conduction band. The donor levels can form narrow impurity bands.

### 3.41 Acceptor Level

An intermediate impurity level close to the valence band in an extrinsic semiconductor.

NOTE — The acceptor level is empty at the temperature of zero Kelvin: at any other temperature it can receive electrons from the valence band. The acceptor levels can form narrow impurity bands.

### 3.42 Surface Level

A local level caused by the presence of an impurity or other imperfection at the surface of the crystal.

### 3.43 Ionizing Energy of Donor

The minimum energy to be applied to an electron located at the donor level in order to transfer it to the conduction band.

### 3.44 Ionizing Energy of Acceptor

The minimum energy to be applied to a valence band electron in order to transfer it to the acceptor level.

### 3.45 Ideal Crystal

A crystal which is perfectly periodic in structure, and accordingly contains no impurities or other imperfections.

### 3.46 Stochiometric Composition

The chemical composition of a compound in which the elements exist in the precise proportions represented by its chemical formula.

### 3.47 Imperfection (of a Crystal Lattice)

A deviation in structure from that of an ideal crystal.

### 3.48 Intrinsic Conductivity

Conductivity of an intrinsic semiconductor.

### 3.49 N-type Conductivity

Conductivity caused by a flow of electrons from a donor.

### 3.50 P-type Conductivity

Conductivity caused by a flow of holes from an acceptor.

### 3.51 Charge Carrier

In a semiconductor, a free conduction electron, or a hole, or an ion.

### 3.52 Majority Carrier

A charge carrier of a type that constitutes more than half of the total free charge carrier concentration.

### 3.53 Minority Carrier

A charge carrier of a type that constitutes less than half of the total free charge carrier concentration.

### 3.54 Excess Carrier

Conduction electron or hole in excess of the number determined by means of the thermodynamic equilibrium.

### 3.55 Conductivity Modulation (of a Semiconductor)

The variation of the conductivity as a result of the injection of excess carriers or the removal of carriers.

### 3.56 Surface Recombination Velocity

The velocity with which minority carriers would have to drift to the surface of the semiconductor in order to account for the rate at which they tend to combine there and are thus lost.

NOTE — The surface recombination velocity is equal to the quotient of:

a) the number of recombinations taking place at the surface per unit time and area, and

b) by the excess minority carrier concentration directly below the surface.

### 3.57 Bulk Lifetime (of Minority Carriers)

The time interval in which a given density of excess minority carriers in the bulk of a homogeneous semiconductor decays by recombination to the fraction $1/e$ of its original value.

### 3.58 (Drift) Mobility (of a Charge Carrier)

A quantity equal to the quotient of the modulus of the mean velocity of a charge carrier in the direction of an electric field by the modulus of the field strength.

### 3.59 Diffusion (in a Semiconductor)

The movement of particles caused only by a concentration gradient.

### 3.60 Diffusion Length (of Minority Carriers)

The distance in which the density of minority carriers decays to the fraction $1/e$ of the original density, during their diffusion in a homogeneous semiconductor.

### 3.61 Diffusion Constant (of Charge Carriers)

The quotient of diffusion current density by the charge carrier concentration gradient.

### 3.62 Charge Carrier Storage (in a Semiconductor)

A local increase in the concentration of charge carriers with respect to that which would exist under equilibrium in the zero-bias state.

### 3.63 Trap

A crystal lattice imperfection or impurity whose energy level is situated in the forbidden band of the semiconductor and which acts as a centre for the capture or recombination of electrons and holes.

### 3.64 PN Boundary

An interface in the transition region between P-type and N-type material at which the donor and acceptor concentrations are equal.

### 3.65 Transition Region

A region between two homogeneous semiconducting regions, in which the electric properties change.

NOTE — The two homogeneous regions are not necessarily of the same semiconductor material.

### 3.66 Impurity Concentration Transition Zone

A zone in which the impurity concentration changes from one value to another.

### 3.67 Neutral Region

A region which is virtually electrically neutral, the negative charges of the electrons and of the ionized acceptor atoms balancing the positive charges of the holes and of the ionized donor atoms.

### 3.68 Potential Barrier

The potential difference between two substances in contact or between two homogeneous regions having different electrical properties, due to the diffusion of charge carriers from each part and the creation of a space charge region.

### 3.69 Potential Barrier (of a PN Junction)

A potential barrier between two points respectively located in the P-type neutral region and the N-type neutral region.

### 3.70 Junction

A transition layer between semiconductor regions of different electrical properties, or between a semiconductors and a layer of different type, being characterized by a potential barrier impeding the movement of charge carriers from one region to the other.

### 3.71 Abrupt Junction

A junction the width of which in the direction of the impurity-concentration gradient is much less than the width of the space charge region.

### 3.72 Progressive Junction

A junction the width of which in the direction of the impurity-concentration gradient is comparable with the width of the space charge region.

### 3.73 PN Junction

A junction between P and N-type semiconductor regions.

### 3.74 Space-Charge Region

A region in which the net charge density is not zero.

NOTE — The net charge is caused by electrons, holes, ionized acceptors and donors.

### 3.75 Space-Charge Region (of a PN Junction)

A space-charge region contained between two neutral regions of types P and N respectively.

### 3.76 Internal Electric Field

An electric field due to the presence of space charges inside a semiconductor.

### 3.77 Depletion Layer (of a Semiconductor)

A region in which the mobile charge carrier concentration is insufficient to neutralize the net fixed charge density of ionized donors and acceptors.

### 3.78 Tunnel Effect (in a PN Junction)

A process whereby conduction occurs through the potential barrier of a PN junction and in which electrons pass in either direction between the conduction band in the N-region and the valence band in the P-region.

NOTE — Tunnel action, unlike the diffusion of charge carriers, involves electrons only. The transit time is practically negligible.

### 3.79 Magnetoresistive Effect

The change of the electrical resistance of a semiconductor or conductor due to a magnetic field.

### 3.80 Piezoresistive Effect (Tensoresistive Effect)

The change of the electrical resistance of a semiconductor or conductor due to mechanical stress.

## SECTION 3 PROCESSING SEMICONDUCTOR MATERIALS

## 4 TERMS RELATED TO PROCESSING OF SEMICONDUCTOR MATERIALS

### 4.1 Growing by Pulling (of a Single Crystal) Growing by Czochralski's Method

The production of a single crystal by gradually withdrawing the developing crystal from the melt.

### 4.2 Growing by Zone Melting (of a Single Crystal)

The production of a single crystal with the aid of a monocrystalline seed by passing a molten zone first through a portion of the monocrystalline seed and then through the polycrystalline semiconductor material closely abutted to the seed.

### 4.3 Zone Refining

The passing of one or more molten zones along a semiconductor crystal for the purpose of reducing the impurity concentration in the crystal.

### 4.4 Zone Levelling

The passing of one or more molten zones through a semiconductor crystal for the purpose of uniformly distributing impurities in the crystal.

### 4.5 Doping (of a Semiconductor)

The addition of impurities to a semiconductor to achieve a desired N-type conductivity or P-type conductivity.

### 4.6 Impurity Compensation

Addition of donor impurities to a P-type semiconductor or of acceptor impurities to an N-type semiconductor, leading to partial, balanced or over-compensation.

### 4.7 Alloy Technique

The formation of a PN junction by fusing a donor or acceptor substance into the surface of a semiconductor crystal.

NOTES

1 The re-crystallized region formed on cooling contains impurity atoms which give rise to N-type, or P-type conductivity, which differs from that of the host crystal.

2 PNP or NPN junctions are usually formed by alloying from opposite sides of the host crystal.

### 4.8 Diffusion Technique

The formation of the region of P-type or N-type conductivity in a semiconductor crystal by diffusing impurity atoms into the crystal.

### 4.9 Planar Technique

The formation of P-type or N-type regions or both in a semiconductor crystal by diffusion technique through apertures in a protective surface layer on the crystal.

### 4.10 Micro-Alloy Technique

The formation of small PN junction by alloying after depositing the acceptor or donor materials in small area pits by a process of electroplating.

### 4.11 Mesa Technique

The formation of a junction in the shape of a raised plateau by successive impurity diffusions or alloying and then etching away material in the regions surrounding the plateau.

### 4.12 Epitaxy

The deposition of a layer of semiconductor material onto a substrate this layer having the same crystal orientation as the substrate.

### 4.13 Surface Passivation

The application or growth of a protective layer on the surface of a semiconductor after the formation of regions of P-type, N-type or both.

### 4.14 Ion Implantation

The formation of a region of P-type, N-type or intrinsic conductivity in semiconductor crystal by implanting accelerated ions.

## SECTION 4 TYPES OF SEMICONDUCTOR DEVICES

## 5 TERMS RELATED TO TYPES OF SEMICONDUCTOR DEVICES

### 5.1 Semiconductor Device

A device whose essential characteristics are due to the flow of charge carriers within a semiconductor.

### 5.2 Semiconductor Diode

A semiconductor device having two electrodes and exhibiting an asymmetrical voltage-current characteristics.

NOTE — Unless otherwise qualified, this term usually means a device with the voltage-current characteristic typical of a single PN junction.

### 5.3 Signal Diode

A semiconductor diode used for detecting or processing electrical signals.

### 5.4 Tunnel Diode

A semiconductor diode having a PN junction in which tunnel action occurs in the forward direction giving rise to negative differential conductance in a certain range of the forward direction of the current-voltage characteristics.

### 5.5 Unitunnel Diode

A tunnel diode whose peak and valley point currents are approximately equal.

### 5.6 Variable-Capacitance Diode

A semiconductor diode used as a voltage-controlled capacitor.

### 5.7 Mixer Diode

A semiconductor diode designed for frequency conversion of signals by means of a local oscillator.

### 5.8 Frequency-Multiplication Diode

A semiconductor diode designed for multiplying the frequency of a signal.

### 5.9 Switching Diode

A semiconductor diode designed for a fast transition from a high-impedance state to a low-impedance state and *vice-versa*, depending on the polarity of the applied voltage.

### 5.10 Voltage Reference Diode

A semiconductor diode which develops across its terminals a reference voltage of specified accuracy when biased to operate within a specified current range.

### 5.11 Voltage Regulator Diode

A semiconductor diode which develops across its terminals an essentially constant voltage throughout a specified current range.

### 5.12 Semiconductor Rectifier Diode

A diode designed for rectification.

### 5.13 Thermistor

A resistor having a large non-linear (generally negative) temperature coefficient of resistance.

### 5.14 Semiconductor Thermoelement

A semiconductor device based on the Seebeck or Peltier effect and designed for direct conversion of heat into electric energy or *vice-versa*.

### 5.15 Hall Effect Device

A semiconductor device in which the hall effect is utilized.

### 5.16 Hall Modulator

A Hall effect device which is specially designed for modulation purposes.

### 5.17 Hall Generator

A Hall plate, together with leads and, where used, encapsulation and ferrous or non-ferrous plates.

### 5.18 Hall Multiplier

A Hall effect device which contains a Hall generator and a coil as source of magnetic flux, such that the output quantity is proportional to the product of the control current and the current producing the magnetic flux.

### 5.19 Hall Probe — Hall Effect Magnetometer

A Hall effect device specifically designed for the measurement of magnetic flux density.

### 5.20 Magnetoresistor

A semiconductor or conductor device in which the dependence of electric resistance on magnetic flux density is used.

### 5.21 Corbino Disc

A disc-shaped magnetoresistor whose two electrodes are a conductive region in the geometric centre of the disc and a concentric conductive strip around the outer perimeter of the disc.

### 5.22 Photodiode

A photoelectric device in which absorption of electromagnetic radiation in the junction and its neighbourhood or at a contact between a semiconductor and a metal, produces a change of resistance or a change of voltage.

### 5.23 Light Emitting Diode (LED)

A diode capable of emitting radiant energy, in the visible region of the spectrum resulting from the recombination of electrons and holes.

### 5.24 Infra-Red Emitting Diode (IRED)

A diode capable of emitting radiant energy, in the infra-red region of the spectrum resulting from the recombination of electrons and holes.

### 5.25 Photoelectric Receptor, Photocell

Physical receptor that depends for its action on an external or internal photoelectric effect.

### 5.26 Photoconductive Cell

A photodiode in which the photoconductive effect is utilized.

### 5.27 Photovoltaic Cell

A photodiode in which the photovoltaic effect is utilized.

### 5.28 Transistor

A semiconductor device capable of providing amplification and having at least three electrodes.

### 5.29 Bipolar Junction Transistor

A transistor having at least two junctions and whose functioning depends on both minority carriers and majority carriers.

### 5.30 Unipolar Transistor

A transistor in which the current flow mechanism is predominantly by majority carriers.

### 5.31 Bidirectional Transistor

A bipolar junction transistor (or field-effect transistor) that has substantially the same electrical characteristics when the electrodes normally designated as emitter (or source) and collector (or drain) are interchanged.

**5.32 Phototransistor**

A transistor in which the photoelectric effect is utilized.

**5.33 Field-Effect Transistor**

A unipolar transistor in which the current flowing through a conduction channel is controlled by an electric field oriented in the direction perpendicular to that of the current.

**5.34 Junction-Gate Field-Effect Transistor**

A field-effect transistor having one or more gate regions which form PN junction(s) with the channel.

**5.35 Insulated-Gate Field-Effect Transistor**

A field-effect transistor having one or more gate electrodes which are electrically insulated from the channel.

**5.36 Metal-Oxide-Semiconductor Field-Effect Transistor; MOSFET (Abbreviation)**

An insulated-gate field-effect transistor in which the insulating layer between each gate electrode and the channel is oxide material.

**5.37 N-Channel Field-Effect Transistor**

A field-effect transistor which has an N-type conduction channel.

**5.38 P-Channel Field-Effect Transistor**

A field-effect transistor which has a P-type conduction channel.

**5.39 Depletion-Type Field-Effect Transistor**

A field-effect transistor which has appreciable channel conductivity at zero gate-to-source voltage and whose channel conductivity may be increased or decreased according to the polarity of the applied gate-to-source voltage.

**5.40 Enhancement-Type Field-Effect Transistor**

A field-effect transistor which has approximately zero channel conductivity at zero gate-to-source voltage and whose channel may be made conductive by the application of a gate-to-source voltage of appropriate polarity.

**5.41 Thyristor**

A bistable semiconductor device comprising three or more junctions which can be switched from the off-state to the on-state, or *vice-versa*.

**5.42 Reverse-Blocking Diode Thyristor**

A two-terminal unidirectional thyristor that switches for positive anode voltage and exhibits a reverse-blocking state for negative anode voltage.

**5.43 Reverse-Blocking Triode Thyristor**

A three-terminal unidirectional thyristor that switches for positive anode voltage and exhibits a reverse-blocking state for negative anode voltage.

**5.44 Reverse-Conducting Diode Thyristor**

A two-terminal unidirectional thyristor that switches only for positive anode voltage and conducts large currents at negative anode voltages comparable in magnitude to the on-state voltage.

**5.45 Reverse-Conducting Triode Thyristor**

A three-terminal unidirectional thyristor that switches only for positive anode voltage and conducts large currents at negative anode voltages comparable in magnitude to the on-state voltage.

**5.46 Bidirectional Diode Thyristor Diac (Abbreviation)**

A two-terminal thyristor having substantially the same switching behaviour in the first and third quadrants of the current-voltage characteristic.

**5.47 Bidirectional Triode Thyristor Triac (Abbreviation)**

A three-terminal thyristor having substantially the same switching behaviour in the first and third quadrants of the current-voltage characteristic.

**5.48 Gate Turn-Off Thyristor**

A thyristor which can be switched from the on-state to the off-state, and *vice-versa*, by applying control signals of appropriate polarity to the gate terminal.

NOTE — The ratio of triggering power to triggered power must be appreciably less than one.

**5.49 P-gate Thyristor**

A unidirectional thyristor in which the gate terminal is connected to the P-region nearest the cathode and which is normally switched to the on-state by applying a positive signal to the gate terminal with respect to the cathode terminal.

**5.50 N-gate Thyristor**

A unidirectional thyristor in which the gate terminal is connected to the N-region nearest the anode and which is normally switched to the on-state by applying a negative signal to the gate terminal with respect to the anode terminal.

**5.51 Photothyristor**

A thyristor that is intended to be responsive to radiant energy as a triggering source.

**5.52 Electrode (of a Semiconductor Device)**

An element that performs one or more of the functions of emitting or collecting electrons or holes, or of controlling their movements.

### 5.53 Substrate

The material upon or within which the semiconductor device or circuit elements are fabricated.

### 5.54 Semiconductor Optoelectronic Device

A semiconductor device that is responsive to, or that emits or modifies, coherent or non-coherent electromagnetic radiation in the visible, infra-red and/ or ultraviolet spectral regions; or a device that utilizes such electromagnetic radiations for its internal operation.

### 5.55 Semiconductor Photoemitter

A semiconductor optoelectronic device that directly converts electrical energy into optical radiant energy.

### 5.56 Semiconductor Laser

A semiconductor optoelectronic device that emits coherent radiant energy through stimulated emission resulting from the recombination of electrons and holes.

### 5.57 Semiconductor Photosensitive Device

A semiconductor device that is responsive to, electromagnetic radiation in the visible, infra-red and/ or ultraviolet spectral regions.

### 5.58 Photocoupler (Optocoupler)

A semiconductor optoelectronic device designed for the transfer of electrical signals by utilizing radiant energy to provide coupling with electrical isolation between the input and the output.

## SECTION 5 GENERAL TERMS FOR SEMICONDUCTOR DEVICES

## 6 SEMICONDUCTOR DEVICES CHARACTERISTICS

### 6.1 Forward Direction (of a PN Junction)

The direction of current that results when the P-type semiconductor region is at a positive voltage relative to the N-type region.

### 6.2 Reverse Direction (of a PN Junction)

The direction of current that results when the N-type semiconductor region is at a positive voltage relative to the P-type region.

### 6.3 Negative Differential Resistance Region

Any portion of the voltage-current characteristic within which the differential resistance is negative.

### 6.4 Breakdown (of a Reverse Biased PN Junction)

Transition from a state of high resistance to a state of substantially lower resistance for increasing magnitude of reverse voltage.

### 6.5 Avalanche Breakdown (of a PN Junction)

A breakdown caused by the cumulative multiplication of charge carriers in a semiconductor under the action of a strong electric field which causes some charge carriers to gain enough energy to create new hole-electron pairs (field-induced impact ionization).

### 6.6 Zener Breakdown (of a PN Junction) Tunnel Breakdown (of a PN Junction)

A breakdown caused by the transition of electrons from the valence band to the conduction band due to tunnel action under the influence of a strong electric field in the reverse direction.

### 6.7 Thermal Breakdown (of a PN Junction)

The breakdown that is caused by generation of free charge carriers owing to the cumulative interaction between increasing power dissipation and increasing junction temperature.

NOTE — The English term "thermal runaway" is also used in some countries.

### 6.8 Punch-Through (Between Two PN Junctions)

Contact between the space charge regions of two PN junctions as a result of widening of one or both of them.

### 6.9 Thermal Resistance

The quotient of the difference between the virtual temperature of the device and the temperature of a stated external reference point, by the steady-state power dissipation in the device.

### 6.10 Virtual Temperature Internal Equivalent Temperature (of a Semiconductor Device)

A theoretical temperature which is based on a simplified representation of the thermal and electrical behaviour of the semiconductor device.

NOTES

1 The virtual temperature is not necessarily the highest temperature in the device.

2 Based on the power dissipation and the thermal resistance or impedance that corresponds to the mode of operation, the virtual junction temperature can be calculated from the formula:

$$T_j = T_{case} + \frac{P}{R_{th}} \qquad \text{or}$$

$$T_\mathrm{j} = T_\mathrm{amb} + \frac{P}{R_\mathrm{th}}$$

### 6.11 Virtual (Equivalent) Junction Temperature

The virtual temperature of the junction of a semiconductor device.

### 6.12 Thermal Capacitance

The quotient of the thermal energy stored in the device by the difference between the virtual temperature of the device and that of specified external reference point.

### 6.13 Floating Voltage

The voltage between an open-circuited terminal and a reference point when specified voltages are applied to all other terminals.

### 6.14 Recovered Charge (of a Diode or Thyristor)

The total charge recovered from a diode or thyristor after switching from a specified forward (on-state) current condition to a specified reverse condition.

NOTE — This charge includes components due to both charge carrier storage and depletion layer capacitance.

### 6.15 Threshold Voltage (of a Diode or Thyristor)

The value of the voltage at the intersection of the straight line approximation of the forward (on-state) current-voltage characteristic and the voltage axis.

### 6.16 Cut-off Frequency

The frequency at which the magnitude of a measured characteristic quantity has decreased to a specified fraction of its low-frequency value.

NOTE — For a transistor, the cut-off frequency usually applies to the small-signal short-circuit forward current transfer ratio for either the common-base or common-emitter configuration.

### 6.17 Delay-Time

The time interval between a step-function change of the input signal level and the instant at which the magnitude of the output signal passes through a specified value which is close to its initial value.

### 6.18 Rise Time

The time interval between the instants at which the magnitude of the pulse at the output terminals reaches specified lower and upper limits respectively when the semiconductor device is being switched from its non-conducting to its conducting state.

NOTE — The lower and upper limits are usually 10 percent and 90 percent respectively of the final amplitude of the output pulse.

### 6.19 Carrier Storage Time

The time interval between the beginning of the fall of the pulse applied to the input terminals of a semiconductor device and the beginning of the fall of the pulse generated by charge carriers at the output terminals.

### 6.20 Fall Time

The time interval between the instants at which the magnitude of the pulse at the output terminals reaches specified upper and lower limits respectively when a semiconductor device is being switched from its conducting to its non-conducting state.

NOTE — The upper and lower limits are usually 90 percent and 10 percent respectively of the initial amplitude of the output pulse.

### 6.21 Forward Recovery Time

The time required for the current or voltage to recover to a specified value after instantaneous switching from a specified forward (on-state) current condition to a specified reverse bias condition.

### 6.22 Reverse Recovery Time

The time required for the current or voltage to recover to a specified value after instantaneous switching from a specified forward (on-state) current condition to a specified reverse bias condition.

## SECTION 6 SPECIFIC TERMS FOR DIODES

## 7 DIODES

### 7.1 Peak Point (of a Tunnel Diode)

The point on the current-voltage characteristic of a tunnel diode corresponding to the lowest voltage in the forward direction, for which the differential conductance is zero.

### 7.2 Valley Point (of a Tunnel Diode)

The point on the current-voltage characteristic of a tunnel diode corresponding to the lowest voltage greater than the peak point voltage, for which the differential conductance is zero.

### 7.3 Projected Peak Point (of a Tunnel Diode)

The point on the current-voltage characteristic of a tunnel diode where the current is equal to the peak point current, but where the voltage is greater than the valley point voltage.

### 7.4 Resistive Cut-off Frequency

The frequency at which the real part of the diode admittance at its terminals is zero, at a specified bias point.

### 7.5 Forward Slope Resistance

The value of the resistance calculated from the slope of the straight line approximation of the forward current-voltage characteristic.

## SECTION 7 SPECIFIC TERMS FOR TRANSISTORS

## 8 TRANSISTORS

### 8.1 Emitter Junction

A junction between the base and emitter regions, normally biased in the forward direction, and through which the charge carriers flow from a region in which they are majority carriers to one in which they are minority carriers.

### 8.2 Collector Junction

A junction between the base and collector regions, normally biased in the reverse direction, and through which the charge carriers flow from a region in which they are minority carriers to one in which they are majority carriers.

### 8.3 Base

A region between the emitter and collector junctions of a bipolar semiconductor device.

### 8.4 Emitter

A region between the emitter junction and the emitter electrode.

### 8.5 Collector

A region between the collector junction and the collector electrode.

### 8.6 Channel (of Field-Effect Transistors)

A thin semiconductor layer between the source region and the drain region, the conductance of which is controlled by the gate voltage.

### 8.7 Source (of Field-Effect Transistors)

A region from which the majority carriers flow into the channel.

### 8.8 Drain (of Field-Effect Transistors)

A region into which majority carriers flow from the channel.

### 8.9 Gate (of Field-Effect Transistors)

A region in which the electric field due to a control gate voltage is effective.

### 8.10 Inverse Direction of Operation

A mode of operating a bipolar junction transistor in which the collector acts as an emitter and in which the net flow of minority carriers is from the collector region to the base region.

### 8.11 Common Base (Arrangement)

A circuit arrangement of a bipolar junction transistor in which the base terminal is common to the input circuit and to the output circuit and in which the input terminal is the emitter terminal and the output terminal is the collector terminal.

### 8.12 Common Collector (Arrangement)

A circuit arrangement of a bipolar junction transistor in which the collector terminal is common to the input circuit and to the output circuit and in which the input terminal is the base terminal and the output terminal is the emitter terminal.

### 8.13 Common Emitter (Arrangement)

A circuit arrangement of a bipolar junction transistor in which the emitter terminal is common to the input circuit and to the output circuit and in which the input terminal is the base terminal and the output terminal is the collector terminal.

### 8.14 Small-Signal Short-Circuit Forward Current Transfer Ratio

The ratio of the alternating output current to the sinusoidal input current producing it under small-signal conditions, the output being short-circuited to alternating current.

### 8.15 Static Forward Current Transfer Ratio

The ratio of the direct output current to the direct input current, the output voltage being held constant.

### 8.16 Transition Frequency ( $f_T$ )

The product of the modulus of the common emitter small-signal short-circuit forward current transfer ratio $|h_{21e}|$ and the frequency of measurement, this frequency being so chosen that $|h_{21e}|$ is decreasing at a slope of approximately 6 dB per octave.

### 8.17 Frequency of Unity Current Transfer Ratio ($f_1$)

The frequency at which the modulus of the common-emitter small-signal short-circuit forward current transfer ratio $|h_{21e}|$ has decreased to unity.

### 8.18 Cut-off Voltage (of a Depletion Type Field-Effect Transistor)

The gate-source voltage at which the magnitude of the drain current reaches a specified low value.

### 8.19 Threshold Voltage (of an Enhancement Type Field-Effect Transistor)

The gate-source voltage at which the magnitude of the drain current reaches a specified low value.

### 8.20 Transconductance (of a Field-Effect Transistor)

The ratio of the increment in the drain current to a corresponding incremental change of the gate-source voltage with the drain-source voltage held constant.

## SECTION 8 SPECIFIC TERMS FOR THYRISTORS

## 9 THYRISTORS

### 9.1 Gate

An auxiliary terminal which controls the switching action of a thyristor.

### 9.2 Principal Current

The current which flows through the device excluding gate current.

### 9.3 Main Terminals

The two terminals through which the main current flows.

### 9.4 Principal Voltage

The voltage between the main terminals.

### 9.5 Principal (Voltage-Current) Characteristic

A function, usually represented graphically, relating the principal voltage to the principal current, with the gate current, where applicable, as a parameter.

### 9.6 Anode-to-Cathode (Voltage-Current) Characteristic, Anode Characteristic

A function, usually represented graphically, relating the anode voltage to the principal current, with the gate current, where applicable, as a parameter.

### 9.7 On-state

The condition of a thyristor corresponding to the low-resistance low-voltage portion of its principal characteristic.

NOTE — In the case of reverse conducting devices, this definition is applicable only for positive anode voltage.

### 9.8 Off-state

The condition of a thyristor corresponding to the position of the principal characteristic between the origin and the breakover point or points.

### 9.9 Reverse Blocking State (of a Reverse Blocking Thyristor)

The condition of a reverse blocking thyristor corresponding to reverse currents of lower magnitude than the current at the reverse breakdown voltage.

### 9.10 Holding Current

The minimum principal current required to maintain a thyristor in the on-state.

### 9.11 Latching Current

The minimum principal current required to maintain a thyristor in the on-state immediately after switching from the off-state to the on-state has occurred and the triggering signal has been removed.

### 9.12 Breakover Point

A point on the principal characteristic for which the differential resistance is zero and where the principal voltage reaches a maximum value.

### 9.13 On-state Slope Resistance

A resistance equal to the slope of the straight line used when determining the threshold voltage from the current-voltage characteristic.

### 9.14 Gate Trigger Current

The lowest gate current required to switch a thyristor from the off-state to the on-state.

### 9.15 Gate Trigger Voltage

The gate voltage required to produce the gate trigger current.

### 9.16 Gate Non-trigger Voltage

The highest gate voltage which will not cause the thyristor to switch from the off-state to the on-state.

### 9.17 Gate Non-trigger Current

The gate current corresponding to the gate non-trigger voltage.

### 9.18 Critical Rate of Rise of Off-state Voltage

The lowest value of the rate of rise of principal voltage that will cause switching from the off-state to the on-state under specified conditions.

### 9.19 Critical Rate of Rise of On-state Current

The highest value of the rate of rise of on-state current which a thyristor can withstand without deleterious effect.

## SECTION 9 SPECIFIC TERMS FOR HALL EFFECT DEVICES AND MAGNETORESISTORS

## 10 HALL EFFECT DEVICES AND MAGNETORESISTORS

### 10.1 Hall Effect

The production in a conductor or in a semiconductor of an electric field strength proportional to the vector product of the current density and the magnetic flux density.

### 10.2 Hall Coefficient

The coefficient of proportionality $R_H$ in the Hall effect quantitative relation:

$$\vec{E}_H = R_H (\vec{J} \times \vec{B})$$

where

$\vec{E}_H$ resulting transverse electric field strength,

$\vec{J}$ current density, and

$\vec{B}$ magnetic flux density.

NOTE — The sign of the majority carrier charge can usually be inferred from the sign of the Hall coefficient.

### 10.3 Hall Angle

The angle which exists, in the presence of Halleffect, between the resulting electric field strength and the current density.

### 10.4 Hall Mobility ( Symbol : $\mu_H$ )

The product of the Hall coefficient and the electric conductivity.

### 10.5 Hall Voltage

The voltage generated by the Halleffect.

### 10.6 Hall Terminals

The terminals of a Hall generator between which the Hall voltage appears.

### 10.7 Control Current Terminals (of a Hall Generator)

The terminals of a Hall generator through which the control current flows.

### 10.8 Effective Induction Area of the Output Loop

The effective area of the loop enclosed by the leads to the Hall terminals and the relevant conductive path through the Hall-effect device.

### 10.9 Effective Induction Area of the Control Current Loop

The effective area of the loop enclosed by the control current leads and the relevant conductive path through a Hall plate by the Hall effect.

### 10.10 Self Field (of a Hall Generator)

The magnetic field caused by the flow of control current through the loop formed by the control current leads and the relevant path through a Hall-effect device.

### 10.11 Control Current (of a Hall Generator)

The current through a Hall plate which generates the Hall voltage by interaction with a magnetic field.

### 10.12 Magnetic Sensitivity (of a Hall Probe)

The quotient of the Hall voltage by the magnetic flux density in the linear operating range of a Hall probe.

### 10.13 Control Current Sensitivity (of a Hall Probe)

The quotient of the Hall voltage by the control current in the linear operating range of a Hall probe.

### 10.14 Residual Voltage for Zero Current Control (of a Hall-Effect Probe)

The voltage which exists at the Hall terminals when a time varying magnetic field is present and the control current is zero.

### 10.15 Residual Voltage for Zero Magnetic Field (of a Hall-Effect Device)

The voltage which exists at the Hall terminals when control current flows under the conditions of no applied magnetic field.

### 10.16 Induced Control Voltage (of a Hall-Effect Device)

The voltage induced in the loop formed by the control current leads and the current path through a Hall plate caused by a varying magnetic flux density.

### 10.17 Magnetoresistive Characteristic Curve

A curve of resistance of a magnetoresistor *versus* magnetic flux density.

### 10.18 Magnetoresistive Coefficient

At a specified magnetic flux density, the quotient of the variation of the resistance with magnetic induction of a magnetoresistor by the resistance at that specified magnetic flux density.

### 10.19 Magnetoresistive Ratio

The ratio of the resistance of a magnetoresistor at a specified magnetic flux density to the resistance at zero magnetic flux density.

### 10.20 Magnetoresistive Sensitivity

The rate of change of the resistance of a magnetoresistor with magnetic flux density at a specified magnetic flux density.

## SECTION 10 SPECIFIC TERMS FOR INTEGRATED MICROCIRCUITS

### 11 INTEGRATED MICROCIRCUITS

### 11.1 Microelectronics

The construction and use of highly miniaturized electronic circuits.

### 11.2 Microcircuit

A miniaturized device having a high concentration of circuit elements and components and considered as a single unit.

### 11.3 Integrated Microcircuit

A microcircuit in which a number of circuit elements are inseparably associated and electrically interconnected such that, for the purpose of specification, testing, application and maintenance, it is considered indivisible.

NOTES

1 For this definition, a "circuit element" does not have an envelope or external connection and is not specified or sold as a separate item.

2 When no misunderstanding can occur the term may be abbreviated to "integrated circuit".

### 11.4 Integrated Circuit

A circuit in which a number of circuit elements are inseparably associated and electrically interconnected such that, for the purpose of specification, testing, application and maintenance, it is considered indivisible.

NOTE — For this definition, a circuit element does not have an envelope or external connection and is not specified or sold as a separate item.

### 11.5 Microassembly

A microcircuit consisting of various components and integrated microcircuits which are constructed separately, and may be tested separately before being assembled and sealed.

NOTE — For the definition, a component has external connections and possibly an envelope as well and it also can be considered as a separate item.

### 11.6 Semiconductor Integrated Circuit

An integrated microcircuit whose elements and interconnections are formed within and upon a semiconductor substrate.

### 11.7 Film Integrated Circuit

An integrated microcircuit whose elements and interconnections are films formed on an insulating substrate.

### 11.8 Thin-Film Integrated Circuit

A film integrated circuit whose films are formed by vacuum deposition techniques, possible supplemented by other deposition techniques.

### 11.9 Thick-Film Integrated Circuit

A film integrated circuit whose films are formed by printing, serigraphy or other related techniques.

## SECTION 11 SPECIFIC TERMS FOR OPTOELECTRONIC DEVICES

### 12 OPTOELECTRONIC DEVICES

### 12.1 Peak-Emission Wavelength

The wavelength at which the spectral radiant intensity is a maximum.

### 12.2 Peak-Sensitivity Wavelength

The wavelength at which the spectral sensitivity is a maximum.

### 12.3 Spectral Radiation Bandwidth

The wavelength interval in which the spectral concentration of a radiometric quantity is not less than half of its maximum value.

### 12.4 Radiation Diagram

A diagram that characterizes the distribution (actual or expected) in space of a radiation emitted by an emitting optoelectronic device.

### 12.5 Half-Intensity Beam Angle

The full cone angle within which the radiant intensity is not less than half of the maximum intensity.

### 12.6 Photoelectric Current

That part of the electric current in a photoelectric receptor which is produced by the photoelectric effect.

### 12.7 Dark Current

That part of the electric current in a photoelectric receptor which still flows when the receptor receives no radiation capable of producing a photoelectric effect.

### 12.8 Optical Axis

A line about which the principal radiant-energy or sensitivity pattern is centered.

NOTES

1 The radiant energy or sensitivity pattern may be non-symmetrical.

2 The optical axis may deviate from the mechanical axis.

### 12.9 Radiant Energy

Energy emitted, transferred or received in the form of radiation.

symbol : $Q_e$, $Q$;     unit: joule, J

NOTE — In ultraviolet radiation therapy and photobiology this quantity is called integral dose.

### 12.10 Radiant Flux, Radiant Power

Power emitted, transferred, or received in the form of radiation.

symbol: $\phi_e$ , $\phi$, $P$; $\phi_e = \frac{d\Phi_e}{dt}$ ; unit: watt, W

### 12.11 Radiant Efficiency (of a Source of Radiation)

Ratio of the radiant flux emitted to the power consumed.

symbol: $\eta_e$, $\eta$

NOTE — The radiant efficiency of a source in a limited region of the spectrum may also be considered, that is the ratio of the radiant flux emitted in this spectral region to the power consumed.

### 12.12 Radiant Intensity (of a Source in a Given Direction)

Quotient of the radiant flux leaving the source, propagated in an element of solid angle containing the given direction, by the element of solid angle.

symbol: $I_e$, $I$; $I_e = \frac{d\Phi_e}{d\Omega}$

unit: watt per steradian, W. $sr^{-1}$

NOTE — For a source which is not a point source. The quotient of the radiant flux received at an elementary surface by the solid angle which this surface subtends at any point of the source, when this quotient is taken to the limit as the distance between the surface and the source is increased.

### 12.13 Radiance (in a Given Direction, at a Point on the Surface of Source or a Receptor, or at a Point on the Path of a Beam)

Quotient of the radiant flux leaving, arriving at, or passing through an element of surface at, or passing through an element of surface at this point and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone and the area of the orthogonal projection of the element of surface on a plane perpendicular to the given direction:

symbol: $L_e$, $L$; $L_e = \frac{d^2\Phi_e}{d\Omega\ dA.\ \cos\theta}$

unit : watt per steradian and per square metre, W. $sr^{-1}$. $m^{-2}$

NOTE — Three special cases may be noted:

*Case A* — At a point on the surface of a source, in a given direction radiance is also the quotient of the radiant intensity in the given direction of an element of the surface at this point, by the area of the orthogonal projection of this element on a plane perpendicular to this direction (Radiant intensity per unit projected area):

$$L_e = \frac{dI_e}{dA.\ \cos\theta}$$

*Case B* — At a point on the surface of a receptor, in a given direction radiance is also the quotient of the irradiance which is received at this point on a surface perpendicular to the given direction, by the solid angle of the elementary cone containing this direction and surrounding the beam which produces this irradiance (Perpendicular irradiance per unit solid angle):

symbol: $L_e = \frac{dE_e}{d\Omega}$

*Case C* — On the path and in the direction of an element of a beam, in a non-diffusing, non-absorbing medium, the radiance is also the quotient of the radiant flux $d\phi_e$ transported by the beam, by the geometric extent $dG$ of the beam. The geometric extent, which may be defined by two sections of the beam of areas $dA$ and $dA_1$ of separation $l$ and having angles $\theta$ and $\phi$: between their normals and the direction of the beam, is $dG = dA \cdot \cos\theta \cdot d\Omega$ where the numerical value in steradians of $d\Omega$ is $dA_1 \cdot \cos\theta \cdot l^{-2}$ .

symbol: $L_e = \frac{d\Phi_e}{dG} = \frac{d^2\Phi_e}{d\Omega\ dA.\ \cos\theta}$

In the absence of diffusion, it can be demonstrated in geometrical optics that the optical extent, product of the geometric extent of an element of a beam and the square of the refractive index of the medium of propagation, is an invariant along the length of the beam whatever the deviations which it undergoes by reflection or refraction ( $dG \cdot n^2$ = constant). In consequence, the basic radiance, quotient of the radiance by the square of the refractive index, is invariant along the length of an element of a beam if the losses by absorption or by reflection are taken as zero ($L_e \cdot n^{-2}$ = constant).

### 12.14 Radiant Flux (Surface) Density (at a Point of a Surface)

Quotient of the radiant flux at an element of the surface containing the point, by the area of that element.

symbol : $= \frac{d\Phi_e}{dA}$

unit : watt per square metre, W.$m^{-2}$

### 12.15 Irradiance (at a Point of a Surface)

Quotient of the radiant flux incident on an element of the surface containing the point, by the area of that element.

symbol: $E_e$, $E$; $E_e = \frac{d\Phi_e}{dA}$

unit: watt per square metre, W. $m^{-2}$

NOTE — In ultraisolate radiation therapy and photobiology this quantity is called dose-rate.

### 12.16 Radiant Excitance (at a Point of a Surface)

Quotient of the radiant flux leaving a length of the surface containing the point by the area of that element.

symbol: $M_e$, $M$; $M_e = \frac{d\Phi_e}{dA} = \int Le \cos\theta \cdot d\Omega$

unit : watt per square metre, W. $m^{-2}$

NOTES

1 The name radiant emittance previously given to this quantity is abondoned because it has given rise to confusion. Thus the term emittance has been used to designate either the flux per unit area leaving a surface (whatever the origin of the flux) or the flux per unit area emitted by a surface (flux originating in the surface), or, principally a quantity without dimensions similar to emissivity but applicable only to a specimen.

2 The expression 'self radiant existance' ($M_e$, $s$) indicates that the flux considered does not include reflected or transmitted flux.
The expression thermal radiant existance ($M_e$ , $th$) indicates that the flux considered is produced by thermal radiation. These same adjectives (self thermal) are equally applicable to other quantities, such as luminance, etc.

3 In the case of a full radiator (black body) the radiance $L_e$ is uniform in all directions. In consequence, when the solid angle is measured in steradians, the radiant existance has the numerical value $M_e = \pi L_e$

### 12.17 Radiation

**12.17.1** Emission or transfer of energy in the form of electromagnetic waves or particles.

**12.17.2** These electromagnetic waves or particles.

NOTE — In general, nuclear radiations and radio waves are not considered in this vocabulary but only optical radiations, that is electromagnetic radiations (photons) of wavelength lying between the region of transition to X-rays (≈1nm) and the region of transition to radio waves (≈1mm).

### 12.18 Visible Radiation (Light)

Any radiation capable of causing a visual sensation directly.

NOTE — The limits of the spectral range of visible radiation are not well defined and may vary according to the user. The lower limit is generally taken between 380 and 400 nm and the upper limit between 760 and 780 nm.

### 12.19 Infra-red Radiation

Radiation for which the wavelengths of the monochromatic components are greater than those for visible radiation and less than about 1 mm.

NOTE — The limits of the spectral range of infra-red radiation are not well defined and may vary according to the user.

### 12.20 Spectrum (of a Radiation)

a) Spatial display of a complex radiation produced by separation of its monochromatic components, and

b) Composition of a complex radiation.

NOTE — Examples of spectrum: continuous spectrum, line spectrum.

### 12.21 Irradiation

Application of radiation to an object.

### 12.22 Point Source

Source of radiation the dimensions of which are small enough, compared with the distance between source and receptor, for them to be neglected in calculations.

### 12.23 Relative Spectral Energy (Power) Distribution (of a Radiation)

Description of the spectral character of a radiation (description of an illuminant) by the relative spectral distribution of some radiometric quantity [radiant flux (power), radiant intensity, etc ].

### 12.24 Luminous Flux

Quantity derived from radiant flux by evaluating the radiation according to its action upon a selective receptor, the spectral sensitivity of which is defined by the standard spectral luminous efficiencies.

symbol : $\phi_v$, $\phi$; unit: lumen, lm

NOTE — Unless otherwise indicated, the luminous flux in question relates to photopic vision, and is connected with the radiant flux in accordance with the formula:

$$V = K_m \int \frac{d\Phi_e}{d\lambda} V(\lambda)\, d\lambda$$

in which $\frac{d\Phi_e}{d\lambda} d\lambda$ is the radiant flux corresponding to the radiation comprised between $\lambda$ and

$\lambda + d\lambda$ and $V(\lambda)$ is the spectral luminous efficiency. Applied to the radiation of a full radiator at the temperature of freezing platinum the preceding formula determines the values of $K_m$ ($l_m$. $W^{-1}$) (*see* **12.26**).

### 12.25 Quantity of Light

Product of luminous flux and its duration.

symbol: $Q_v$, $Q$; $Q_v = \int \phi_v\, dt$

unit: lumen-second, lm.s

### 12.26 Luminous Efficacy (of Radiation)

Quotient of luminous flux by the corresponding radiant flux.

For a complex radiation symbol $K$; $K = \frac{\Phi_v}{\Phi_e}$

For a monochromatic radiation of wavelength λ (spectral luminous efficacy)

$$\text{symbol: } K(\lambda);\ K(\lambda) = \frac{\Phi_{\mathrm{v}},\lambda}{\Omega_{\mathrm{e}},\lambda} = \frac{\mathrm{d}\Phi_{\mathrm{v}}/\mathrm{d}\lambda}{\mathrm{d}\Phi_{\mathrm{e}}/\mathrm{d}\lambda} = K_{\mathrm{m}}\ V(\lambda)$$

where maximum value of $K(\lambda) = K_{\mathrm{m}}$

Unit: lumen-per watt, lm. $\mathrm{W}^{-1}$

### 12.27 Luminous Intensity (of a Source in a Given Direction)

Quotient of the luminous flux leaving the source, propagated in an element of solid angle containing the given direction, by the element of solid angle.

$$\text{symbol: } I_{\mathrm{v}}, I;\quad I_{\mathrm{v}} = \frac{\mathrm{d}\Phi_{\mathrm{v}}}{\mathrm{d}\Omega}$$

unit : candela, cd

NOTES

1 *See* Note under **12.12**.

2 The term candle power designates a luminous intensity expressed in candelas.

### 12.28 (Luminous ) Sector Flux (of a Rectilinear Source of Negligible Cross of Infinite Length in a Direction Perpendicular to its Axis)

Quotient of the luminous flux emitted by unit length of the source in the section included between the planes passing through the source enclosing the given direction and making between them an infinite simal angle, by that angle.

symbol: *J*; unit: lumen per metre and per radian, $l_{\mathrm{m}}$. $\mathrm{m}^{-1}$. $\mathrm{rad}^{-1}$

NOTE — It is presumed that the flux considered in this definition is independent of the part of the source considered.

The illuminance, *E*, for a plane element normal to the direction and situated at a distance, *l*, on a perpendicular to the source is $E = j\ .\ l^{-1}$. This formula gives an approximation useful in the case where ends of the source are sufficiently far away from the plane element considered.

### 12.29 Luminance (in a Given Direction, at a Point on the Surface of a Source or a Receptor or at a Point on the Path of a Beam)

Quotient of the luminous flux leaving, arriving at, or passing through an element of surface at this point and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone and the area of the orthogonal projection of the element of surface on a plane perpendicular to the given direction.

$$\text{symbol: } L_{\mathrm{v}}, L;\quad L_{\mathrm{v}} = \frac{\mathrm{d}^2\Phi_{\mathrm{v}}}{\mathrm{d}\Omega\ \mathrm{d}A.\ \cos\theta}$$

unit: candela per square metre, cd. $\mathrm{m}^{-2}$

NOTES

1 Three special cases may be noted:

*Case A* — At a point on the surface of a source, in a given direction, luminance is also the quotient of the luminous intensity in the given direction of an element of the surface at this point, by the area of the orthogonal projection of this element on a plane perpendicular to this direction (Luminous intensity per unit projected area):

$$\text{symbol: } L_{\mathrm{v}} = \frac{\mathrm{d}I_{\mathrm{v}}}{\mathrm{d}A.\ \cos\theta}$$

*Case B* — At a point on the surface of a receptor, in a given direction, luminance is also the quotient of the illuminance which is received at this point on a surface perpendicular to the given direction, by the solid angle of the elementary cone containing this direction and surrounding the beam which produces this illuminance (Perpendicular illuminance per unit solid angle):

$$\text{symbol: } L_{\mathrm{v}} = \frac{\mathrm{d}E_{\mathrm{v}}}{\mathrm{d}\Omega}$$

*Case C* — On the path and in direction of an element of a beam, in a non-diffusing non-absorbing medium, the luminance is also the quotient of the luminous flux $\mathrm{d}\Phi_{\mathrm{v}}$ transported by the beam, by the geometric extent d*G* of the beam. The geometric extent, which may be defined by two section of the beam of areas d*A* and $\mathrm{d}A_1$ of separation *l* and having angles *θ* and $\theta_1$ between their normals and the direction of the beam, is d*G* = d*A*. cos *θ*. dΩ where the numerical value is steradians of dΩ is $\mathrm{d}A_1$. cos*θ*. $l^{-2}$.

$$\text{symbol: } L_{\mathrm{v}} = \frac{\mathrm{d}\Phi_{\mathrm{v}}}{\mathrm{d}G} = \frac{\mathrm{d}^2\Phi_{\mathrm{v}}}{\mathrm{d}\Omega\ \mathrm{d}A,\ \cos\theta}$$

In the absence of diffusion, it can be demonstrated in geometrical optics that the optical extent, product of the geometric extent of an element of a beam and the square of the refractive index of the medium of propagation, is an invariant along the length of the beam whatever the deviations which it undergoes by reflection or refraction ( $\mathrm{d}G.n^2$ = constant). In consequence, the basic luminance, quotient of the luminance by the square of the refractive index, is invariant along the length of an element of a beam if the losses by absorption or by reflection are taken as zero ( $L_{\mathrm{v}}.\ n^{-2}$ = constant).

2 On the use of the adjective self and thermal (*see* Note 2 under **12.16**).

### 12.30 Equivalent Luminance (of a Field of Given Size and Shape, for a Radiation of Arbitrary Relative Spectral Composition)

Luminance of a comparison field in which the radiation has the same spectral composition as that of a full radiator at the temperature of freezing platinum and which has the same luminosity as the field considered under the specified photometric conditions of measurement; the comparison field must have a specified size and shape which may be different from that of the field considered.

symbol: $L_{eq}$ ; unit: candela per square metre, cd. $m^{-2}$

NOTE — A comparison field may also be used, in which the radiation has a spectral composition different from that of a full radiator at the temperature of freezing platinum ($T68 = 2\,045\ K$), if the equivalent luminance of this field is known under the same conditions of measurement.

### 12.31 Luminous Flux (Surface) Density (at a Point of a Source)

Quotient of the luminous flux at an element of the surface containing the point, by the area of that element.

symbol: $\frac{d\Phi_V}{dA}$

unit: lumen per square metre, lm. $m^{-2}$

NOTE — *See also* **12.33** and **12.41**.

### 12.32 Point Brilliance

Quantity involved in the visual observation of a source of light when viewed directly from such a distance that the apparent diameter is inappreciable. The point brilliance is measured by the illuminance produced by the source on a plane, at the observer's eye, normal to the direction of the source.

symbol: $E_v$, $E$; unit: lux, lx

### 12.33 Luminous Existance (at a Point of a Source)

Quotient of the luminous flux leaving an element of the surface containing the point, by the area of that element.

symbol: $M_v$, $M$; $M_v = \frac{d\Phi_V}{dA} = \int L_v \cos\theta \cdot d\Omega$

unit : lumen per square metre, lm. $m^{-2}$

NOTES

1 Formerly luminous emittance ( *see also* Note 1 under **12.16** ).

2 On the use of the adjectives self and thermal ( *see* Note 2 under **12.16**).

3 The case of a full radiator (black body) or of a uniform diffuser the luminance $L_v$ is uniform in all directions. In consequence, when the solid angle is measured in steradians, the luminous existance has the numerical value $M_V = \pi L_V$.

### 12.34 Amplitude of Fluctuation of the Luminous Intensity (of a Source Run on Alternating Current)

Relative amplitude of the periodic fluctuation of luminous intensity as measured by the ratio of the difference between the maximum and the minimum luminous intensity, to the maximum value:

$$\frac{I_{Max} - I_{Min}}{I_{Max}}$$

### 12.35 Unsteadiness (of the Light Emitted by a Source)

Irregular or slowly periodic fluctuations of the luminous intensity.

NOTE — These fluctuations are unrelated to the frequency of the electrical supply if the source is fed by alternating current.

### 12.36 Mean Value of Photometric Quantity

(same definitions as for an electrical quantity).

NOTE — This quantity may be time and/or space dependent.

### 12.37 Peak Value of Photometric Quantity

Maximum value of the photometric quantity; this quantity may be time and/or space dependent.

### 12.38 Luminescence

Phenomenon of the emission by matter of electromagnetic radiation which for certain wavelengths or restricted regions of the spectrum is in excess of that due to the thermal radiation from the material at the same temperature. The radiation is characteristic of the particular material.

NOTE — In lighting this term is generally restricted to the emission of radiation in the visible or near visible spectrum.

### 12.39 Photoluminescence

Luminescence caused by ultraviolet, visible or infra-red radiation.

### 12.40 Electroluminescence

Luminescence of certain substances, generally solid, under the action of an electric field.

NOTE — Formerly this term has been used chiefly for the luminescence of a gas under the action of an electric discharge.

### 12.41 Illuminance: Illumination (at a Point of a Surface)

Quotient of the luminous flux incident on an element of the surface containing the point, by the area of that element.

symbol: $E_V$, $E$; $E_V = \frac{d\Phi_v}{dA}$

unit: lux, lx.

### 12.42 Spectral Concentration (of a Photometric Quantity: Luminous Flux, Luminous Intensity, etc)

Quotient of the photometric quantity $X_v$, taken over an infinitesimal range on either side of a given wavelength by the range.

$$X_v, \lambda = \frac{dX_v}{d\lambda}$$

NOTE — Frequencies, wave-numbers or their logarithms may also be used; if there is a risk of ambiguity, this should be avoided by means of the wording: spectral concentration in terms of frequency, etc.

### 12.43 Spectral Distribution (of a Photometric Quantity: Luminous Flux, Luminous Intensity, etc)

The spectral concentration of the photometric quantity as a function of wavelength.

NOTES

1 *See* Note under **12.42**.

2 Commonly the relative spectral distribution is used, that is, the spectral concentration of the photometric quantity measured in terms of an arbitrary value of this quantity.

### 12.44 Mean Spherical (Luminous) Intensity (of a Source)

Average value of the luminous intensity in all directions.

NOTE — It is also the quotient of the luminous flux by the solid angle 4π steradians.

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